In the Specification

[0001] The invention relates to a method and a device for the edge-machining of a plastic optical lens ~~in accordance with the preambles to claims 1 and 20~~ with a controlled angle of rotation about a rotated axis and to a combination tool therefor ~~in accordance with the preamble to claim 12~~ for edge machining of an optical lens. In particular, the invention relates to the industrial, ie optimised with regard to accuracy and machining speed, machining of the edges of spectacle lenses made of plastics, such as polycarbonate, CR39 and so-called "HI-index" materials.

[0017] ~~This object is achieved by the features disclosed in claims 1, 12 or 20. Advantageous or expedient further embodiments of the invention are the subject of claims 2 to 11 and 13 to 19.~~

[0018] According to one of the basic concepts of the invention, in a method for the edge-machining of an optical lens L, namely a plastic spectacle lens that may be rotated with a controlled angle of rotation φ_B about a rotational axis of a workpiece B, in which the edge R of the lens L is first preliminary machined by means of a combination tool which is at least radially adjustable relative to the rotational axis of the workpiece B and rotatable about a rotational axis of a tool C, whereby the lens is provided in plan view with a circumferential contour U which corresponds to a circumferential contour of a holder for the lens L apart from a slight degree of

oversizing if necessary, and in which the edge R of the lens L is then finish-machined by means of the combination tool, whereby when viewed in cross section the edge R of the lens L is provided with a pre-specified edge geometry in accordance with the intended method for securing it to the holder, optionally provided with a protective chamfer F_1, F_2 at the transition to one or both optically effective surfaces O_1, O_2 and optionally polished, the preliminary machining of the edge R and the finish-machining of the edge R takes place by means of a combination tool which comprises both milling cutters and at least one ~~turning~~ lathe tool with said combination tool being rotated at a controlled rotational speed n_c about the rotational axis of the tool C during a milling machining of the edge R, and being swivelled with a controlled angle of rotation φ_c about the rotational axis of the tool C before and optionally also during a ~~turning~~ lathe machining of the edge R.

[0019] In addition, the invention discloses in particular for the performance of the aforementioned method a combination tool for the edge-machining of an optical lens L, namely a plastic spectacle lens, with a base body on which is provided a plurality of milling cutters that, when the combination tool is rotated about a rotational axis of a tool C, define a cutting circle and by means of which the edge R of the lens L can in particular be subject to preliminary machining in such a way that, seen in plan view, the lens L is provided with a circumferential contour U which corresponds to a circumferential contour of a holder for the lens L apart from a slight degree of oversizing if necessary whereby the combination tool is characterised by the fact that the base body is also provided with at least one ~~turning~~ lathe tool commonly referred

to as a lathe tool that is arranged axially displaced with regard to the milling cutters in the direction of the rotational axis of the tool C, or is arranged at the axial height of the milling cutters in the circumferential direction of the combination tool between the milling cutters with a ~~turning~~ lathe cutter that is radially internally displaced in relation to the cutting circle of the milling cutters, whereby the ~~turning~~ lathe tool has a cutter geometry by means of which the edge R of the lens L may be in particular finish-machined so that the edge R of the lens L has a prespecified edge geometry according to the intended method of securing it to the holder when viewed in cross section and/or is provided with a protective chamfer F_1, F_2 at the transition to one or both optically effective surfaces O_1, O_2 and/or is polished.

[0020] Finally, according to the invention, in the case of a device that is in particular suitable for the performance of the above method using in particular the aforementioned combination tool for the edge-machining of an optical lens L, namely a plastic spectacle lens, with two aligned holding shafts rotatable with a controlled angle of rotation φ_B about a rotational axis of a workpiece B between which the lens L may be clamped, and that has a tool spindle, by means of which the combination tool may be driven rotationally about a rotational axis of a tool C running substantially parallel to the rotational axis of the workpiece B, whereby the holding shafts and the tool spindle may be moved with position control towards each other in a first axial direction X and optionally parallel to each other in a second axial direction Z perpendicular to the first axial direction X, for the ~~turning~~ lathe machining of the edge R of the lens L, the combination tool may be swivelled with a controlled angle of

rotation φ_C about the rotational axis of the tool C by means of the tool spindle so that a ~~turning~~ lathe tool provided on the combination tool may be brought into a defined ~~turning~~ lathe machining engagement with the edge R to be machined.

[0021] In essence, therefore, as far as the method is concerned, the invention is based on employing or using for the edge-machining of a plastic optical lens, in particular a spectacle lens, a combination tool by means of which both a milling machining operation and a ~~turning~~ lathe machining operation on the edge R of the lens L is possible. In this way, by a milling machining operation, in which the combination tool is rotated at a controlled rotational speed n_c about the rotational axis of the tool C, relatively high quantities of material from the lens L can be machined in a very short time in order, for example, to provide the lens L in a preliminary machining step, seen in plan view, with a circumferential contour U that corresponds to the circumferential contour of the holder for the lens apart from a slight degree of oversizing if necessary. The similarly facilitated ~~turning~~ lathe operation, before or during which the combination tool is swivelled with a controlled angle of rotation φ_C about the rotational axis of the tool C, can then be used for the finish-machining of the edge R of the lens L in order, in dependence on the cutter geometry of the ~~turning~~ lathe tool, to provide the edge R of the lens L, when viewed in cross section, with a prespecified edge geometry in accordance with the intended means of securing it to the holder and/or to create a protective chamfer at the edge R of the lens L at the transition to one or both optically effective surfaces O_1, O_2 and/or to polish the edge R of the lens L. A substantial advantage of the ~~turning~~ lathe

machining of the edge R enabled by the invention, in which the ~~turning~~ lathe tool is in a defined rotational angle setting or only tracked or swivelled with a controlled angle of rotation φ_c, over the (fine) grinding known from prior art, in which the grinding tool is rotated about the rotational axis of the tool, is seen in the fact that, depending upon the cutter geometry of the ~~turning~~ lathe tool, during the ~~turning~~ lathe machining of the edge R, when viewed in the circumferential direction said ~~turning~~ lathe tool may be in a substantially punctiform machining engagement with the edge R of the lens L. If, in the case of punctiform machining engagement of this type with a ~~turning~~ lathe tool with a corresponding cutter geometry, a bevel edge S is placed on the edge R of the lens L, for example, thereby performing a relative axial movement of the combination tool relative to the lens L parallel to the rotational axis of the workpiece B in order, as described above, to machine the bevel edge S at different heights on the edge R of the lens L, there is no longer any risk of the "smearing" of the bevel edge S which is thereby provided with a geometry precisely prespecified by the cutter geometry of the ~~turning~~ lathe tool.

[0022] As far as the tool is concerned, proposed in essence is a combination tool that is so-to-speak a combination of a milling cutter and a ~~turning~~ lathe tool revolver. Compared to a grinding tool, a ~~turning~~ lathe tool enables the implementation of significantly more and different cutter geometries so that edge geometries can be achieved on the lens L, for example the slot or groove N described at the beginning, with a ~~turning~~ lathe tool having a corresponding ~~turning~~ lathe cutter, while the grinding tool in the combination tool according to prior art is unable to achieve edge

geometries of this kind; prior art rather requires complicated machining with additional tools and the associated peripherals (spindle, drive, adjustment mechanisms, etc).

[0023] In one embodiment according to the invention, the at least one ~~turning~~ lathe tool is arranged axially displaced relative to the milling cutters so that the ~~turning~~ lathe tool may also protrude over the cutting circle of the milling cutters without colliding with the edge R during the milling of the edge R of the lens L. This is a simple way to create additional design scope with regard to the design of the ~~turning~~ lathe tool or the ~~turning~~ lathe tool's cutter geometry and should again be evaluated as advantageous with regard to the flexibility of the tool concept as far as the plurality of possible edge geometries is concerned. Compared to the known combination tools, the proposed combination tool can nevertheless have a very short axial length since, even if its ~~turning~~ lathe cutter is wider than the maximum edge thickness of the lens L to be machined therewith or the lens L which has been machined therewith, the ~~turning~~ lathe tool can still be kept much narrower than the grinding tools in the known combination tools. This very compact design of the combination tool in the axial direction is conducive to good machining quality, to be more precise to high surface finishes, insofar that the combination tool has an only slight tendency to vibrate if any. Here, it should also be noted that a short combination tool may also be arranged close to the tool spindle mounting together with the possibility of using short holding shafts for the lens L, which contributes

overall to a very rigid edger construction and accordingly lenses L may be machined more quickly with a better machining quality.

[0024] In an alternative embodiment according to the invention, the ~~turning~~ lathe tool, with a ~~turning~~ lathe cutter which is radially internally displaced relative to the cutting circle of the milling cutters, is arranged at the axial height of the milling cutters in the circumferential direction of the combination tool between the milling cutters so that during the continuous rotation of the combination tool during a milling operation the ~~turning~~ lathe cutter is unable to be brought into machining engagement with the edge R of the lens L. One advantage of this embodiment may be seen in the fact that the combination tool may be built even shorter for the achievement of excellent machining quality without impairing the machining options.

[0025] It should also be noted with regard to the combination tool according to the invention that for a ~~turning~~ lathe machining operation following a milling machining operation, the combination tool may first be stopped and then be angle-positioned with its ~~turning~~ lathe tool relative to the edge R of the lens L to be machined. The ~~turning~~ lathe tool may therefore be designed completely independently of the milling cutters with regard to the cutter geometry (in particular the geometry of the milling cutter and the rake angle and clearance angle) and the cutting material and accordingly optimally adapted to the material of the lens L.

[0026] Finally, as far as the device is concerned, the device known for example from DE 101 14 239 A1 of the applicant, which is position-controlled in the two linear axes X and Z and angle-controlled in the rotational axis of the workpiece B, is simply

supplemented by another (CNC-) controlled axis, namely the angle-controlled rotational axis of the tool C. This permits the swivel-positioning of the combination tool with regard to the edge R of the lens L to be machined so that the combination tool's ~~turning~~ lathe tool may always be brought into a defined ~~turning~~ lathe machining engagement with the edge R of the lens L to be machined.

[0027] In sum, the edge R of the lens L to be machined may be subjected to both a milling machining operation with a relatively high machining volume and a (fine) ~~turning~~ lathe machining operation with only one combination tool which, in addition to milling cutters has at least one ~~turning~~ lathe tool, in only one device and with only one clamping of the lens L so that a plurality of edge geometries [extensive design possibilities for the ~~turning~~ lathe tool's cutting edge geometry] of high quality, ie improved geometric accuracy when viewed macrogeometrically [viewed in a circumferential direction, substantially punctiform machining engagement is possible] and high surface quality when viewed microgeometrically [a vibration-avoiding or reducing short design of the combination tool is possible; extensive design scope for the cutter geometry of the ~~turning~~ lathe tool with regard in particular to the rake and clearance angles] may be machined rapidly and reliably.

[0028] The invention will be further described with reference to preferred embodiments shown in the attached, to some extent schematic, drawings. These show:

Fig. 1 A perspective view of a combination tool according to the invention in accordance with a first embodiment, which is in ~~turning~~ lathe

machining engagement with the edge R of a lens L to be machined,

Fig. 2 a side view of the combination tool according to Fig. 1 which is in ~~turning~~ lathe machining engagement with the edge R of the lens L to be machined,

Fig. 3 a side view corresponding to Fig. 2 of the first embodiment in which the combination tool is cut and the lens L is shown partially broken off,

Fig. 4 a cross-sectional view corresponding to the line indicated at IV-IV in Fig. 2 in a larger scale than that used in Fig. 2,

Fig. 5 an enlarged representation of detail V in Fig. 4,

Fig. 6 an enlarged representation of detail VI in Fig. 4,

Figs. 7-19 side views, which correspond in the manner of representation to Fig. 2, of the first embodiment showing the edge-machining processes that may be performed with the combination tool according to the first embodiment,

Fig. 20 (A) – (G) schematic diagrams of a combination tool according to the invention in a plan view illustrating how a ~~turning~~ lathe tool in the combination tool is moved or tracked by superposed control in the X-axis [x (φ_B, r_B (φ_B)] and the C-axis [φ_C, (φ_B, r_B (φ_B))] in dependence on the angle of rotation φ_B of the lens L and its radius r_B (φ_B) during the edge-machining,

Fig. 21 a perspective view of a combination tool according to the invention according to a second embodiment which is in ~~turning~~ lathe machining engagement with the edge R of a lens L to be machined and has a different design of the milling cutters as compared to the first embodiment,

Fig. 22 a side view of the combination tool according to Fig. 21 which is in ~~turning~~ lathe machining engagement with the edge R of the lens L to be machined,

Fig. 23 a perspective view of a combination tool according to the invention according to a third embodiment which is in ~~turning~~ lathe machining engagement with the edge R of a lens L to be machined and has a different design of the milling cutters as compared to the first and

second embodiments,

Fig. 24 a side view of the combination tool according to Fig. 23 which is in ~~turning~~ lathe machining engagement with the edge R of the lens L to be machined,

Fig. 25 a perspective view of a combination tool according to the invention according to a fourth embodiment which is in ~~turning~~ lathe machining engagement with the edge R of a lens L to be machined and has a different design of the milling cutters as compared to the first to third embodiments,

Fig. 26 a side view of the combination tool according to Fig. 25 which is in ~~turning~~ lathe machining engagement with the edge R of the lens L to be machined,

Fig. 27 a side view of a combination tool according to the invention according to a fifth embodiment which is in ~~turning~~ lathe machining engagement with the edge R of a lens L to be machined and in which, unlike the first to fourth embodiments, the ~~turning~~ lathe tools are arranged at the axial height of the milling cutters in the circumferential direction of the combination tool between the milling cutters with ~~turning~~ lathe cutters which are radially internally displaced in relation to the cutting circle of the milling cutters,

Fig. 28 a cross-sectional view corresponding to the line indicated at XXVIII-XXVIII in Fig. 27 in a larger scale than that used in Fig. 27, and

Figs. 29-32 broken off cross-sectional views of spectacle lenses L in the area of the edge R illustrating the currently usual basic edge geometries on spectacle lenses with finished edges.

[0030] To simplify the representation, the only parts of the device for the edge-machining of plastic spectacle lenses L shown schematically in Figs. 1 to 6 are the tool spindle 12 bearing a combination tool 10, whereby said spindle may be driven

rotationally about the rotational axis of the tool C, and the two aligned holding shafts 14, 16 that may be driven rotationally about the rotational axis of the workpiece B between which shafts the spectacle lens L may be clamped. Here, the rotational axis of the workpiece B and the rotational axis of the tool C are parallel to each other. The holding shafts 14, 16 may be rotated with a controlled angle of rotation φ_B about the rotational axis of the workpiece B by means of a suitable drive and allocated control (not shown). In addition, the holding shafts 14,16 and the tool spindle 12 may be moved with position control towards or away from each other in a first axial direction X and parallel to each other in a second axial direction Z perpendicular to the first axial direction X. Expediently, these axial movement options during the edge-machining are assigned to the tool spindle 12. Provided for this are suitable slides with allocated guides and drives and ~~a~~ an allocated control in each case (not shown). In this regard, express reference is made to the applicant's DE 101 14 239 A1. Novel compared thereto is the fact that for the ~~turning~~ lathe machining of the edge R of the lens L to be machined, the combination tool 10 may be also swivelled with a controlled angle of rotation φ_C about the rotational axis of the tool C by means of the tool spindle 12 for which a suitable drive and allocated control (not shown) are also provided. Both the holding shafts 14, 16 and the tool spindle 12 may, therefore, be rotated at a controlled rotational speed n_B, n_C and with a controlled angle of rotation φ_B, φ_C.

[0037] As demonstrated in particular by Figs. 1 to 4, at least one ~~turning~~ lathe tool 36 is provided on the base body 20, in the embodiment shown there is a plurality of ~~turning~~ lathe tools 36 that are axially displaced in the direction of the rotational axis of the tool C relative to the milling cutters 26, 28 or to be more precise are arranged axially between the upper milling cutters 26 and the lower milling cutters 28. As will be explained in more detail in the following, the ~~turning~~ lathe tools 36 have a cutter geometry by means of which the spectacle lens L may be finish-machined at the edge R in such a way that, viewed in section, the spectacle lens L is provided in particular with a prespecified edge geometry corresponding to the intended means of securing it to the holder with, for example, a bevel edge S or a groove N, and/or provided with a protective chamfer F_1, F_2 at the transition to one or both optically effective surfaces O_1, O_2, and/or is polished. The axial displacement of the ~~turning~~ lathe tools 36 relative to the milling cutters 26, 28 means that the ~~turning~~ lathe tools 36 may also protrude radially outside the cutting circle defined by the milling cutters 26, 28, which is indicated in Fig. 4 by the dotted line at 38, without interfering with the milling machining of the edge R of the spectacle lens L.

[0038] Since in the embodiment shown, several ~~turning~~ lathe tools 36 are provided on one and the same combination tool 10, ~~turning~~ lathe tools 36 differing from each other may be used which – as will be explained in greater detail below – as far as their geometry and/or the milling material – for example hard metal with or without an wear-resistant coating or even PCD, CVD or natural diamond for the polishing of the edge R by means of the ~~turning~~ lathe tool 36 - are concerned are

individually adapted to the edge geometry to be created and/or the desired surface quality and/or to the material of the spectacle lens L to be machined, so that there is no need to change the combination tool 10 even for machining spectacle lenses L with different edge geometries, desired surface qualities or materials. The uniform distribution of the ~~turning~~ lathe tools 36 on the circumference of the base body 20 envisaged in this embodiment has the advantage that due to the ~~turning~~ lathe tools 36, very little or no unbalance occurs such as could be detrimental to the surface quality of the edge surface created when the combination tool 10 is used for milling.

[0039] Although, in principle, it is possible to form the at least one ~~turning~~ lathe tool in one piece with the base body, for example to solder it to the base body like the milling cutters, preferred is the design of the combination tool 10 shown here with which the ~~turning~~ lathe tool 36 is secured detachably to the base body 20. To be precise, this advantageously permits the replacement of individual ~~turning~~ lathe tools 36 or their temporary separation from the combination tool 10 for reworking. For this purpose, introduced in the base body 20 as shown in Figs. 3 and 4 is a plurality of, in the embodiment shown, six, blind holes 40 each with a suitable, for example circular, hole section, which when viewed in section according to Fig. 4, run in a radial direction, ie in the direction of the rotational axis of the tool C, and which, when viewed in longitudinal section according to Fig. 3, run under an angle of 90° relative to the rotational axis of the tool C. The blind holes 40 which, as already mentioned, have uniform angular spacing from each other, are used for the positive accommodation of a metallic shaft 42 of a ~~turning~~ lathe tool 36. For this purpose, the

shaft 42 of the ~~turning~~ lathe tool 36 has a cross section that is substantially complementary to the cross section of the blind hole 40. The end of the shaft 42 of the ~~turning~~ lathe tool 36 in question accommodated in the allocated blind hole 40 lies on the base of the allocated blind hole 40 and is secured detachably in this position by a grub screw 44, which for this is screwed into an allocated threaded hole 46 in the base body 20 from where it extends into a recess 48 formed in the shaft 42. The threaded holes 46 lie in a common plane running perpendicular to the rotational axis of the tool C and extend under an angle of 90° to the blind hole 40 allocated in each case. It is evident that in this way the ~~turning~~ lathe tools 36 may be fixed to the base body 20 in a tension-proof and compression-resistant way and protected against torsion.

[0040] The ~~turning~~ lathe tools 36 shown in Figs. 1 to 19 have been selected from a group comprising the following ~~turning~~ lathe tools 36, whereby is should be noted in advance that the ~~turning~~ lathe tools 36 described may be combined with each other on a combination tool 10 as desired according to the machining requirements.

[0041] (A) ~~Turning~~ lathe tools 36 with a ~~turning~~ lathe cutter with a width b that is greater than a maximum edge thickness of the spectacle lens L machined or to be machined therewith. A ~~turning~~ lathe tool 36 of this type with a straight, ~~turning~~ lathe cutter running parallel to the rotational axis of the tool C is shown in operation in Fig. 13 and may be used to perform the preliminary machining of the edge R of the spectacle lens L by means of a ~~turning~~ lathe tool. However, here it is preferable that the preliminary machining of the edge R of the lens L be performed by means of the

milling cutters 26 of the combination tool 10 since this achieves a greater removal of material in a shorter time without the risk of swarf formation possibly affecting the machining quality. Insofar, the ~~turning~~ lathe tools 36 in question here are primarily used with an edge shape of the spectacle lens L according to Fig. 29 to polish the edge R for which the ~~turning~~ lathe tool 36 in particular has a specific cutter geometry that will be described in more detail in the following with reference to Figs. 5 and 6. With this machining, the position control of the combination tool 10 in the X-axis is performed in dependence on the angle of rotation φ_B of the spectacle lens L, as described with reference to Fig. 7, but with different feed rates. The swivel movement of the combination tool 10 about the rotational axis of the tool C will be further described with reference to Fig. 20; the same applies to the ~~turning~~ lathe tools 36 described in the following.

[0042] (B) ~~Turning~~ lathe tools 36 whose ~~turning~~ lathe cutter preferably has a central V-shaped recess 50 used to form a bevel edge S on the edge R of the spectacle lens L as shown in Fig. 30. A ~~turning~~ lathe tool 36 of this kind with an otherwise straight ~~turning~~ lathe cutter running parallel to the rotational axis of the tool C is shown in operational use in Fig. 14. It is evident that with a ~~turning~~ lathe tool 36 of this kind, the two flanks K_1, K_2 of the bevel edge S may be created in one pass. Here, the position control of the combination tool 10 in the X-axis and optionally the Z-axis is performed in dependence on the angle of rotation φ_B of the spectacle lens L as described with reference to Fig. 8.

[0043] (C) ~~Turning~~ lathe tools 36 whose ~~turning~~ lathe cutter has on at least one end a chamfer 52, 54 for the formation of a flank K_1, K_2 of a bevel edge S (see Fig. 30) on the edge R of the spectacle lens L and/or for the creation of a protective chamfer F_1, F_2 (see Fig. 32) at the edge R of the spectacle lens L. Figs. 15 and 16 show a ~~turning~~ lathe tool 36 of this kind with an otherwise straight ~~turning~~ lathe cutter running parallel to the rotational axis of the tool C in operation whereby, however, only the formation of one bevel edge S is illustrated. Accordingly, first one flank K_2 of the bevel edge S is formed by the chamfer 52 on the upper end of the ~~turning~~ lathe cutter in Fig. 15 and then the other flank K_1 of the bevel edge S is formed by the chamfer 54 at the other end, ie the lower end in Fig. 16, of the ~~turning~~ lathe cutter. Here, the combination tool 10 is position-controlled in dependence on the angle of rotation φ_B of the spectacle lens L according to the desired circumferential contour U of the machined spectacle lens L in the X-axis and, where necessary, according to the desired height profile of the bevel edge S or the protective chamfers F_1, F_2 on or at the edge R of the spectacle lens L in the Z-axis.

[0044] (D) ~~Turning~~ lathe tools 36 whose ~~turning~~ lathe cutters have a width b less than or greater than the width of a slot or groove N to be created at the edge R of the spectacle lens L as depicted in Fig. 31. A ~~turning~~ lathe tool 36 of this kind whose ~~turning~~ lathe cutter preferably has a cutting edge with a complementary shape to the desired cross section of the groove N to be formed in the edge R of the spectacle lens L is shown inter alia in operation in Fig. 19. Once again, during this fine- or finish-machining step the combination tool 10 is position-controlled in dependence

on the angle of rotation φ_B of the spectacle lens L according to the desired circumferential contour U of the machined spectacle lens L and the desired depth of the groove N in the X-axis and, where necessary, according to the desired height profile of the groove N at the edge R of the spectacle lens L in the Z-axis.

[0045] (E) ~~Turning~~ lathe tools 36 whose ~~turning~~ lathe cutter has, for the creation of protective chamfers F_1, F_2 (see Fig. 32) on the edge R of the spectacle lens L two adjoining straight cutting areas 56, 58 forming a prespecified angle with each other. Figs. 17 and 18 show a ~~turning~~ lathe tool 36 of this kind in operation whereby the cutting areas 56, 58 may be formed in specular symmetry in relation to a plane running perpendicular to the rotational axis of the tool C and form an angle of, for example, 90° with each other. Accordingly, first one protective chamfer F_1 is formed by the cutting area 58 on the lower side of the ~~turning~~ lathe cutter in Fig. 17 and then the other protective chamfer F_2 is formed by the cutting area 56 on the other, ie the upper side of the ~~turning~~ lathe cutter in Fig. 18. Here, the combination tool 10 is position-controlled in dependence upon the angle of rotation φ_B of the spectacle lens L according to the desired circumferential contour U of the machined spectacle lens L and the desired width of the protective chamfers F_1, F_2 in the X-axis and, where required, according to the height profile of the edge R of the spectacle lens L in the Z-axis.

[0046] (F) ~~Turning~~ lathe tools 36 for polishing the edge R of a spectacle lens L made of a relatively soft plastic such as polycarbonate which according to Fig. 6 may have a negative rake angle γ, which may be up to $-15°$ and/or whose area 62 of the

free surface 64 adjoining the face 60 according to Figs. 5 and 6 has a clearance angle α equal or approximately equal to zero before subsequently optionally assuming a positive value. Whereas the above describes measures on the ~~turning~~ lathe cutters of the ~~turning~~ lathe tools 36 according to (A) to (E) that take place in a plane which contains the rotational axis of the tool C of the combination tool 10 in order by means of (fine) ~~turning~~ lathe machining to influence the macrogeometry of the edge R of the spectacle lens L according to Figs. 29 to 32, Figs. 5 and 6 show measures on the cutter geometry of the ~~turning~~ lathe tool 36 in a plane perpendicular to the rotational axis of the tool C by means of which influence may be exerted by means of fine machining on the microgeometry of the edge R of the spectacle lens L, ie on the surface quality of the edge R or parts thereof.

[0047] The described design of the clearance angle α in the area 62 of the free surface 64 adjoining the cutting edge of the ~~turning~~ lathe tool 36 or the rake angle γ of the face 60 achieves two different effects which may also be used independently of each other according to the requirements in question, ie although not shown in Figs. 5 and 6, the cutter geometry of the ~~turning~~ lathe tool 36 may also be selected in such a way that only the rake angle γ has a negative angle while the clearance angle α is much higher than zero at each point of the free surface 64. With a negative value for the rake angle γ (see Fig. 6), during the (fine) ~~turning~~ lathe machining the cutting edge of the ~~turning~~ lathe tool 36 is so-to-speak pulled over the machined edge R of the spectacle lens L whereby the cutting edge pushes away the lens material rather than cutting it as in the case with a positive rake angle γ. As a result,

there is a plastic (cold) deformation of the lens material during which the surface roughness is smoothed.

[0048] If the clearance angle α in the area 62 of the free surface 64 adjoining the face 60 is equal to zero or approximately zero (see Figs. 5 and 6), the (fine) ~~turning~~ lathe machining results in the "compression" of the free surface area 62 against the edge R of the spectacle lens L. As a result of the friction between the free surface area 62 and the edge R of the spectacle lens L moved relative thereto, depending upon inter alia the relative speed in the circumferential direction, the feed rate of the combination tool 10 in the X-axis, the material used for the cutter of the ~~turning~~ lathe tool 36 and the spectacle lens L and the lubricating conditions – heat is introduced into the edge R with said heat resulting in the plastification or softening of the lens material at the edge R which in turn results in the smoothing of the edge surface.

[0049] It is evident to the person skilled in the art that, where technically expedient, it must also be possible to combine the measures taken on the ~~turning~~ lathe tools 36 according to (A) to (F) with each other. In particular, the ~~turning~~ lathe tools 36 according to (A) to (E) may also have a cutter geometry according to (F).

[0050] As a supplement to Figs. 5, 6 and 13 to 19, Fig. 20 illustrates the superposed movements of the ~~turning~~ lathe tool 36 in the combination tool 10 about the rotational axis of the tool C and in the X-axis during the (fine) ~~turning~~ lathe machining of the edge R of a spectacle lens L with a rectangular circumferential contour U. By means of regulation in the C-axis, before the (fine) ~~turning~~ lathe machining of the edge R of the spectacle lens L, the combination tool 10 is first

swivelled about the rotational axis of the tool C in such a way that the ~~turning~~ lathe tool or, in the case of several ~~turning~~ lathe tools 36, one specific ~~turning~~ lathe tool 36, optionally with the radial adjustment of the combination tool 10 relative to the rotational axis of the workpiece B, ie possible position control in the X-axis, is subsequently brought into contact with the edge R of the spectacle lens L in a prespecified relative position between the ~~turning~~ lathe tool 36 and edge R in which the face 60 of the ~~turning~~ lathe tool 36 forms a prespecified angle with a tangent T applied at the edge R at the point of contact with the ~~turning~~ lathe tool 36. In this way, a defined ~~turning~~ lathe machining engagement is achieved between the ~~turning~~ lathe tool 36 and the edge R of the lens.

[0051] If, as in the example shown here, the circumferential contour U of the spectacle lens L deviates from the circular, during the (fine) ~~turning~~ lathe machining of the edge R of the lens L which rotates with a controlled angle of rotation φ_B, the combination tool 10 which is moved or adjusted in a suitable radial manner, ie in the X-axis relative to the rotational axis of the workpiece B, is swivelled, with the angle of rotation φ_C being controlled depending upon the angle of rotation φ_B and the radius $r_B(\varphi_B)$ to be created of the spectacle lens L -- $\varphi_C = f\,[\varphi_{B,}\, r_B\,(\varphi_B)]$ -- about the rotational axis of the tool C in such a way that the prespecified angle between the face 60 of the ~~turning~~ lathe tool 36 and the tangent T at the point of contact between the ~~turning~~ lathe tool 36 and the edge R substantially remains constant in order to maintain the defined ~~turning~~ lathe machining engagement between the ~~turning~~ lathe tool 36 and the edge R of the lens to achieve the desired machining results. Therefore, this is a

CNC-controlled, continuous tracking of the ~~turning~~ lathe cutter of the ~~turning~~ lathe tool 36 whereby, as Fig. 20 shows, there may also be a reversal of the direction of the swivel movement of the combination tool 10 about the rotational axis of the tool C.

[0052] It is evident from the above description that the proposed combination tool 10 performs the preliminary machining of the edge R of the spectacle lens L in particular by means of the milling cutters 26, 28 in the combination tool 10 rotating at a controlled rotational speed n_c about the rotational axis of the tool C before the finish-machining of the edge R of the spectacle lens L takes place in particular by means of one or more ~~turning~~ lathe tools 36 provided on the combination tool 10, under a swivel movement with a controlled angle of rotation φ_C of the combination tool 10 about the rotational axis of the tool C. Hereby, before the preliminary machining of the edge R and/or between the preliminary machining and the finish-machining of the edge R, expediently, the edge R of the spectacle lens L is measured with regard to radius values $r_B(\varphi_B)$ and optionally height values $z_B(\varphi_B)$ (see Figs. 29 to 32) following which the preliminary machining or finish-machining of the edge R is performed taking into account the measured values $r_B(\varphi_B)$, $z_B(\varphi_B)$. With regard to a suitable measuring method, here express reference is made to applicant's DE 101 19 662 A1.

[0055] In the third embodiment according to Figs. 23 and 24, the combination tool 10 has only one milling section which is arranged axially displaced in relation to the ~~turning~~ lathe tool 36. Here, the milling section has a plurality of milling cutters 70 of which, as shown in a rather schematic way in Figs. 23 and 24, in the circumferential direction adjacent milling cutters 70 run inclined relative to the rotational axis of the tool C in opposite directions, ie once to the left and once to the right and the oppositely inclined milling cutters 70 are arranged alternately on the circumference of the base body 20. As a result of this arrangement, the milling cutters 70 form a cross-shaped structure on the base body 20 which is left and right-cutting. Compared to the first and second embodiments, this results in even lower process forces and even more greatly reduced swarf formation on both sides. Once again, the inclination of the milling cutters 70 achieves a reduction in the impact effect of the individual milling cutter 70 and hence the reduced induction of vibrations during the milling. In addition, the still existent radial eccentricity of the combination tool 10 does not take full effect. Similarly, as with the first and second embodiments, according to the machining requirements in question, the V-shaped recesses 30 and/or the chamfers 32, 34 on the milling cutters 26, 28 or 66, 68 may also be omitted, and, if necessary, the milling section in the third embodiment may also have V-shaped recesses and/or terminal chamfers.

[0056] Figs. 25 and 26 illustrate with reference to a fourth embodiment of the combination tool 10 a greatly simplified design of the milling section compared to the first to third embodiments in which the milling cutters 72 run parallel to the rotational

axis of the tool C. Milling cutters 72 of this kind, which optionally may have a V-shaped recess and/or terminal chamfers in accordance with the first and second embodiments, are particularly simple to produce and rework.

[0057] Finally, with the fifth embodiment of the combination tool 10 according to Figs. 27 and 28, the ~~turning~~ lathe tools 36 are arranged at the axial height of the milling cutters 74, which in this embodiment run parallel to the rotational axis of the tool C, in the circumferential direction of the combination tool 10 with a uniform angular distribution between the milling cutters 74, and each have a ~~turning~~ lathe cutter radially internally displaced relative to the cutting circle 38 of the milling cutters 74. Here, the ~~turning~~ lathe tools 36 are secured to the base body 20 in a similar way to the securing of the ~~turning~~ lathe tools 36 described for the first embodiment. This design has the advantage that the combination tool 10 is even shorter than the first to fourth embodiments in the axial direction, ie in the direction of the rotational axis of the tool C. In the fifth embodiment, the milling cutters 74 may again have V-shaped recesses and/or terminal chamfers. Finally, it is also feasible to have an arrangement of the ~~turning~~ lathe tools 36 of this kind at the axial height of the milling cutters viewed in the circumferential direction between the milling cutters even with the designs of the milling cutters described with reference to the first to third embodiments. Optionally, then one or more sector(s) on the base body 20 would be kept free of milling cutters and the ~~turning~~ lathe tool(s) 36 would be provided at this/these places.

[0058] A device is disclosed for edge-machining in particular plastic spectacle lenses with two aligned holding shafts rotatable with a controlled angle of rotation φ_B about a rotational axis of a workpiece B between which the lens may be clamped and a tool spindle by means of which a combination tool may be driven rotationally about a rotational axis of a tool C running parallel to the rotational axis of the workpiece B. The holding shafts and the tool spindle may be moved with position control towards each other in a first axial direction X and optionally parallel to each other in a second axial direction Z perpendicular to the first axial direction X. According to the invention, for a ~~turning~~ lathe machining of the edge R of the lens, the combination tool can be swivelled with a controlled angle of rotation φ_C about the rotational axis of the tool C by means of the tool spindle so that a ~~turning~~ lathe tool provided on the combination tool may be brought into a defined ~~turning~~ lathe machining engagement with the edge R of the lens. The invention also comprises a combined milling and ~~turning~~ lathe tool and a combined milling and ~~turning~~ lathe machining method. As a result, the edge of the lens may be machined very flexibly, quickly and with a high machining quality.